PSYCHE.

THE SCALES OF COLEOPTERA.

BY GEORGE DIMMOCK, CAMBRIDGE, MASS.

Altho the following paper is mainly a description of a few forms of scales of coleoptera, on some of which the scales have not before been noticed, and on others of which they have been more or less fully described, a brief outline of the history and bibliography of the knowledge of the scales of insects in general and of coleoptera in particular may not be amiss as an introduction to these descriptions.

According to Mayer[1] and Schneider[2] the scales of lepidoptera were first mentioned, by Fabricius, in 1600, were later mentioned by Malpighi, in 1650, and since then by many other observers. Up to the beginning of the present century the literature of this subject is of little importance except historically, and I will cite only the names of Bonanni, Ledermüller, Réaumur, Rösel and Swammerdamm, who made mention, to a greater or less extent, of the scales of lepidoptera in their works. During the present century the literature of this subject has increased rapidly, and among the authors of leading papers which treat mainly or considerably of the scales of lepidoptera are, in chronological order, Deschamps (1835),[3] Bowerbank (1838),[4] Craig (1839),[5] Ratzeburg (1840),[6] de la Rue (1852),[7] Semper (1857),[8] Kettelhoit (1860),[9]

[1] Mayer, F. J. C. Ueber den Staub der Schmetterlingsflügel. (Allgem. med. Central-Zeit., 1860, jahrg. 29, p. 772-774.) *Hagen, Bibl. entom.*

[2] Schneider, R. Die Schuppen an den verschiedenen Flügel- und Körpertheilen der Lepidopteren. Dissertatio . . . Halis Saxonum, 1878. Also (Zeitschr. f. ges. Naturw., 1878.)

[3] Deschamps, B. Recherches microscopiques sur l'organisation des ailes des lépidoptères. (Ann. sci. nat., 1835, s. 2, v. 3, p. 111-137.)

[4] Bowerbank, J. S. On the structure of the scales on the wings of lepidopterous insects. (Entom. mag., 1838, v. 5, p. 300-304.)

[5] Craig, E. On the configuration of the scale of butterflies' wings, as exhibited in the microscope. (Edinb. philos. mag., 1839, s. 2, v. 15, p. 279-282, fig.)

[6] Ratzeburg, J. T. C. Die Forstinsekten . . . Bd. 2, 1840.

[7] de la Rue, W. On the markings on the scales of *Amathusia horsfieldii*. (Trans. micros. soc. Lond., 1852, v. 3, p. 36-40, pl. 2.)

[8] Semper, C. Beobachtung über die Bildung der Flügel, Schuppen und Haare bei den Lepidopteren. (Zeitschr. f. wiss. Zool., 1857, v. 8, p. 326-339, pl. 13.)

[9] Kettelhoit, T. De squamis lepidopterorum. Dissertatio . . . Bonnae, 1860.

Mayer (1860),[1] Landois (1871),[10] and Schneider (1878).[2] Even special modifications of scales, called by Scudder[11] androconia, have been found on the males of a large number of butterflies, and have given rise to considerable discussion in regard to their function. Androconia were first discovered about 1825 by Baillif, who termed them plumulae. They have been discussed since in papers by numerous writers, among whom may be mentioned Deschamps[3], Schneider,[2] Watson (1865-1869),[12-15] Wonfor (1868-1869),[16] Anthony (1872),[17-18] Fritz Müller (1877),[19] Scudder (1877),[11] Weismann (1878)[20] and Aurivellius (1880).[21] Weismann believes that it is not impossible that these scales give out an etherial oil secreted by the cells at their bases. Without discussing the correctness of Weismann's view, the extensive literature devoted to the scales of lepidoptera, of which I have given only the outline, shows how broad the subject is. But how is it with the scales of insects other than lepidoptera? Are forms as interesting as androconia waiting the search of thoro investigators?

Leeuwenhoek, in 1680, and Swammerdamm,[22] in the next century, figure the scales of the wings and body of *Culex*, and Weismann,[23] in 1864, speaks of scales on *Sarcophaga carnaria*. These are all the references which I know to diptera having scales and I

[10] Landois, H. Beiträge zur Entwicklungsgeschichte der Schmetterlingsflügel in der Raupe und Puppe. (Zeitschr. f. wiss. Zool., 1871, v. 21, p. 305-316, pl. 23.)

[11] Scudder, S. H. Antigeny, or sexual dimorphism in butterflies. (Proc. Amer. acad. arts and sciences, 1877, v. 12, p. 150-158.)

[12] Watson, J. On certain scales of some diurnal lepidoptera. (Mem. Lit. and phil. soc. Manchester, 1865, s. 3, v. 2, p. 63-70.)

[13] Watson, J. On the microscopical examination of plumules . . . (Entom. mo. mag., 1865, v. 2, p. 1-2, fig.)

[14] Watson, J. On the plumules or battledore scales of *lycaenidae*. (Mem. Lit. and phil. soc. Manchester, 1869, s. 3, v. 3, p. 128-133, pl. 1-3.)

[15] Watson, J. Further remarks on the plumules or battledore scales of some of the lepidoptera. (Mem. Lit. and phil. soc. Manchester, 1869, s. 3, v. 3, p. 259-269, pl. 5-7.)

[16] Wonfor, F. W. On certain butterfly scales characteristic of sex. (Quart. journ. micros. sci., 1868, n. s., v. 8, p. 80-83, pl. 1; 1869, v. 9, p. 19-22, p. 426-428.)

[17] Anthony, J. The markings on the battledore scales of some of the lepidoptera. (Mo. micros. journ., 1872, v. 7, p. 1-3, pl. 1-2.)

[18] Anthony, J. Structure of battledore scales. (Mo. micros. journ., 1872, v. 7, p. 250.

[19] Müller, Fritz. Ueber Haarpinsel, Filzflecke und ähnliche Gebilde auf den Flügeln männlicher Schmetterlinge. (Jena. Zeitschr. f. Naturw., 1877, bd. 11, p. 99-114.)

[20] Weismann, A. Ueber Duftschuppen. (Zool. Anzeiger, 1879, Jahrg. 1, p. 98-99.)

[21] Aurivellius, C. Ueber sekundäre Geschlechtscharaktere nordischer Tagfalter. (Bihang till k. Svenska vet.-akad. handlingar, 1880, bd. 5, n:o 25.)

[22] Swammerdamm, J. Buch der Natur. . . . Leipzig, 1752.

[23] Weismann, A. Die nachembryonale Entwickelung der Musciden. . . . (Zeitschr. f. wiss. Zool., 1864, bd. 14, p. 187-336.

will add here to their number, that I have found scales upon the legs of a species of *Ploas* from Germany.

Scales have been examined, but not extensively studied, which were obtained from *thysanura* (*Lepisma*, *Machilis* and *Podura*). L. Landois[24] speaks of scales in *Phthirius*, but it is evident from his description that they are not homologically and structurally like the scales of lepidoptera. Leydig,[25] to whose paper I shall have occasion to refer later, mentions scales resembling those of lepidoptera on spiders of the genus *Salticus*. Claus[26] says the *phryganidae* are "with hairy or scaly wings," but I know of no special studies made upon the scales of these insects. As far as I have been able to discover, scales have only been recorded on hemipterous insects in the case of the curious dimorphic form of *Aphis aceris* (originally described by Thornton, in 1852, as *Phyllophorus testudinatus*) which is figured and briefly described by Packard,[27] and have never been recorded from hymenoptera.

I come now to what is more strictly the subject of this paper, the scales of coleoptera, the literature of which I have, as far as possible, seen and studied.

The earliest mention that I have found of scales on coleoptera is in 1762, by Geoffroy,[28] who not only mentioned scales on several *curculionidae*, but also noticed those of *dermestidae* and *scarabaeidae*. The next notice of scales of coleoptera is in 1773, by Drury,[29] in his description of *Entimus imperialis*, where he alludes to the scales upon this species of *curculionidae*. In 1777, Lindenberg[30] figured and briefly described *Entimus imperialis* and the scales which render it so brilliant. In 1780 the same author[31] gave quite an extended description, accompanied by colored figures, of the scales of *Entimus*. Lindenberg's last paper is partly devoted to a curious consideration of the question why insects and small animals, some of them requiring a microscope to reveal their beauty, were made even more beautiful than larger animals. Since the above-mentioned papers were published, many

[24] Landois, L. Untersuchungen über die auf dem Menschen schmarotzenden Pediculinen. Anatomie des *Phthirius inguinalis* Leach. (Zeitschr. f. wiss. Zool., 1864, v. 14, p. 1-41, pl. 1-5.)

[25] Leydig, F. Zum feineren Bau der Arthropoden. (Müller's Archiv, 1855, p. 376-480, pl. 15-18.)

[26] Claus, C. Grundzüge der Zoologie. 4te Aufl. 1880.

[27] Packard, A. S. Guide to the study of insects . . . Salem, 1869, p. 520-521.

[28] Geoffroy, E. L. Histoire abregée des insectes qui se trouvent aux environs de Paris . . . v. 1, 1762. [See especially p. 69, 78-79, 114, 115, 277, 282-283, 288, 289, 293, 293, 295 and 299.]

[29] Drury. Illustrations of natural history . . . v. 1, 1773.

[30] Lindenberg. Beschreibung eines brasilischen Rüsselkäfers. (Der Naturforscher, 10tes Stück, Halle, 1777, p. 86-87, fig.)

[31] Lindenberg. Ausführlichere Beschreibung des . . . brasilischen Rüsselkäfers, nebst einigen Betrachtungen. (Der Naturforscher, 14tes Stück, Halle, 1780, p. 211-220, fig.)

popular descriptions and brief notes upon the scales of coleoptera have been printed, especially in handbooks for microscopists, but the important contributions to the subject are in Dujardin's Manual for the microscope,[32] in Deschamps' Researches on the elytra of coleoptera[33] and lastly in Fischer's somewhat extensive dissertation[34] on the scales of coleoptera, published in 1846. Fischer's dissertation was based upon a large collection of coleoptera of Europe, which he examined and considered by families. He classified the scales of *curculionidae* into four groups and made a fifth group of the kind of scales found on *Anthrenus*. These divisions will be considered later, in connection with the form and structure of the scales.

I will begin the descriptive part of my paper with an explanation of the hairs of *Cicindela dorsalis*, for I wish to say a good deal about scale-like hairs in this paper, since the scales of coleoptera are simply flattened hairs of a more or less complex nature. In the progress of this paper I hope to be able to point out affinities, not previously noted, between hairs and scales of coleoptera.

HAIRS OF CICINDELA DORSALIS.

The white hairs which clothe the sides of the thorax of *C. dorsalis* and are abundant upon nearly all parts of the under side of this insect, even upon its legs and upon some of its mouth-parts, owe their white color to the presence of air in their interior.

In transverse section these hairs — for they are scarcely flat enough to be termed scales — are circular, ellipsoidal (as in fig. 1, *d*) or with a slight tendency to be triangular. The central

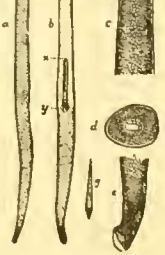

Fig. 1. Hairs of *Cicindela dorsalis*: *a*, from thorax; *b*, same partly deprived of air; *c*, apical end of same; *d*, transverse section of same; *e*, basal end of same; *g*, hair from antenna. Enlargement: *a*, *b* and *g*, 100 diam.; *c*, *d* and *e*, 300 diam.

portion is a canal, about one-fourth the diameter of the whole hair, and is filled with air. This canal is surrounded by very minute cavities forming a sort of pith-like substance filled with air and extending outward to the outer chitinous covering of the hair. The cavi-

[32] Dujardin, F. Nouveau manuel complet de l'observateur au microscope. Avec atlas. Paris. 1843.

[33] Deschamps, B. Recherches microscopiques sur l'organisation des élytres des coléoptères. (Ann. sci. nat., 1845. s. 3. v. 3. p. 354-363.)

[34] Fischer, L. H. Microscopische Untersuchungen über die Käferschuppen. Dissertation . . . Freiburg. 1846. fig. Reprint (Isis. 1846, v. 6, p. 401-421. fig.)

ties or interstices of the pith-like portion open into the central canal of the hair, but are prevented from direct communication with the outer air by the thin sheath of chitin which forms the outer covering of each hair. Each hair is closed at the apex (fig. 1, *c*) by this outer, impervious chitin layer and at its basal end (fig. 1, *e*) by a thickening of the chitin sheath to such an extent as to entirely close the central canal, with its surrounding pith-like substance, from the outer air. This structure, together with the mode of closing of the basal end, leaves the nature of the development of the hair very apparent. It is a closed sacciform appendage of the external chitinous covering of the insect, as are the scales of lepidoptera, coleoptera and diptera. The knob formed by the basal end (fig. 1, *e*) of the hair is inserted into a pit in the chitin covering of the insect, almost exactly as the corresponding part of the scales of other insects are attached.

The structural points above described were obtained in two ways; first, by sectioning the hairs with the microtome, and, second, by carefully observing under the microscope the action of different reagents on the hairs. I obtained a few good transverse sections of hairs taken from the sides of the thorax, and, by examination of these sections, verified the existence of an open central canal. Fig. 1, *d*, shows one of these sections which was about 0.01 mm. in thickness and about 0.02 mm. in average diameter, drawn with the camera. The expulsion of the air from these hairs, when they were broken at any point, was readily effected by chloroform or alcohol, and scarcely less readily by glycerin, by turpentin, or even by water, but if the hair had not been injured at any point the air was not driven out by any of these reagents, even after several days action. When the air has been expelled from a hair, the latter becomes transparent, and is colorless with directly transmitted light in all parts except where the chitin is thickened to close the base; this chitin is slightly brown. By obliquely transmitted light, obtained by Aubé's illuminating apparatus, the hairs which have been deprived of air exhibit a slightly bluish shade. Fig. 1, *b*, represents a hair of which the distal end has been deprived of air, the part from *x* to *y* is partly deprived of air and the basal portion is still filled with air. Sometimes, especially when glycerin or turpentin is used to expel the air, a part of the air will remain collected in the central canal (fig. 1, *x* to *y*) quite a while after it has left the cavities of the pith-like portion. The clearly defined outline of this column of air led to the suspicion of an open canal, the presence of which was later proved by sections.

The hairs from different parts of *C. dorsalis* vary little in form and size. Those from the thorax and from the under side of the abdomen are club-shaped (fig. 1, *a* and *b*), are from 0.28 to 0.35 mm. in length, and from 0.015 to 0.025 mm. in diameter. They taper gradually and slightly from the middle toward

both ends; the apex is usually truncated (fig. 1, *c*). The basal part forms a slight neck just above the point of insertion (fig. 1, *e*). These hairs are but slightly curved, but are so inserted as to lie nearly flat on the surface of the insect. The hairs (fig. 1, *g*) from the antennae are the smallest of the white hairs on *C. dorsalis*. They are only about 0.07 mm. long and scarcely 0.01 mm. in diameter near the base, from which they taper to their acute tip. The longest hairs are those from the labial palpi, of which the second joint only is densely hairy. These hairs are from 0.30 to 0.50 mm. long, and about 0.015 mm. in diameter near their base, from which they taper gradually to a fine, acute apex. They are considerably curved and slenderly filiform.

Between and upon the hairs of this beetle are yellow, amorphous masses, quite transparent, and apparently secreted from the surface of the insect, altho they may be remnants of some matrix in which the hairs are packed during the pupal state of the insect. Fischer mentions substances of apparently similar nature in his dissertation,[34] and Hagen,[35] in 1882, further discusses them. These masses on *C. dorsalis* often take beautifully clear impressions of the hairs themselves, and are insoluble in water, alcohol, turpentin, glycerin or chloroform.

With the exception of the elytra, labrum and parts of the mandibles, all white portions of *C. dorsalis* owe their creamy whiteness to the hairs described above; these hairs are set on shining, cupreous or green-bronze surfaces.

The hairs upon the sides of the thorax of *C. vulgaris* and *C. puritana* are similar in structure and general form to hairs from the same region in *C. dorsalis*, but they are smaller in *C. puritana* (0.18 mm. long by 0.01 mm. in diameter) and slimmer in *C. vulgaris* (0.55 mm. long and about 0.01 mm. in diameter); in the latter species they are not so abundant.

Taking the families of coleoptera in their systematic order, I examined next the scales of

ANTHRENUS SCROPHULARIAE.

The figuration of the whole body and even of the legs of this insect is due to scales which are not imbricated as are

Fig. 2. Scales of *Anthrenus*: *a*, of *A. scrophulariae*; *b*, arrangement of same on portion of an elytron; *c*, scales of *A. varius*. Enlargement: *a* and *c*, 100 diam., *b*, 50 diam.

the scales of lepidoptera. The basal end of each scale is inserted in a cavity which is at the bottom of a funnel-shaped deepening of the chitinous surface of the insect, and the scales are arranged to a certain extent, altho rather irregularly, in lines. Fig. 2, *b* shows

[35] Hagen, H. A. On the color and the pattern of insects. (Proc. Amer. acad. arts and sciences, 1882, v. 17, p. 234-267.)

their order on a portion of an elytron, the little circle about the base of each scale showing the limits of the funnel-shaped depression in which each scale is inserted. These scales are about 0.05 mm. long by 0.03 mm. wide. They are of three different colors — white, light brown and black—and they all contain air. These scales were described by Fischer and I introduce and figure them here (fig. 2, *a*) only because they furnish a good example of what Fischer termed fibrous scales (Faserschuppen).

Of other species of *dermestidae* I only examined *Dermestes lardarius* and *Anthrenus varius*, for I have had access to but a portion of my collection, which I hope to examine more thoroughly later. The former species was clothed with hairs only.

SCALES OF ANTHRENUS VARIUS.

The figuration of *A. varius* is due, like that of *A. scrophulariae*, to scales which do not imbricate. The scales of *A. varius* (fig. 2, *c*) are narrower than those of *A. scrophulariae*, being about 0.05 mm. long by 0.015 mm. wide. In color they are either dark brown, yellow or white; and they are striate, but the striae, about six in number, are rather obscured by the presence of much air in the scales until the latter are treated with liquid reagents. The fine notching at the apical end of scales of *A. varius* is not so evident as it is in those of *A. scrophulariae*, as can be seen by comparing fig. 2, *a* with fig. 2, *c*, both of which figures are equally enlarged.

At this point may be noted the presence of two sorts of hairs on the larvae of certain *dermestidae*, as described by De Geer,[36] Dujardin[32] and Thevenet, [37-38] and the existence of scales on the larvae of *Attagenus pellio*, as described and figured by Dujardin.[32] the latter species being, so far as I can discover, the only coleopteron from the larva of which scales are known.

The *scarabaeidae* contain a number of genera in which scales are the rule rather than the exception, and, among them, for the first time, comes the consideration of brilliantly colored scales, those of the genus *Hoplia*.

SCALES OF HOPLIA COERULEA.

This well-known European insect is light metallic blue above and silvery beneath, but when deprived of the scales to which its metallic coloration is due, it is brown. The scales of the elytra and upper surface of the thorax are imbricated; those of the abdomen, legs and under side are not imbricated.

The scales of *H. coerulea* vary in form from round to ovate and lanceolate, most

---

[36] De Geer, C. Mémoires pour servir à l'histoire des insectes . . . v. 4. 1774. p.——— pl. 8, fig. 4-6.

[37] Thevenet, J. Note sur les poils de la larve de *l'anthrenus verbasci*. (Ann. Soc. entom. Fr., 1874, s. 5, v. 4: Bull, p. 84, 97.)

[38] Thevenet. J. Note sur les poils de la larve du *megatoma serra*. (Ann. Soc. entom. Fr., 1874, s. 5, v. 4; Bull., p. 112.)

of those from the upper side being usually nearly round and smooth (fig. 3, *a*), while those of the under side are more variable in shape and are always

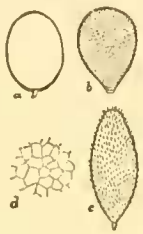

Fig. 3. Scales of *Hoplia coerulea*: *a*, from elytron; *b*, from under side of thorax; *c*, from femur; *d*, fine structure to be seen in *a* with high powers. Enlargement: *a*, *b* and *c*, 100 diam.; *d*, 500 diam.

covered with spines or hairs (fig. 3, *b* and *c*). The scales upon the legs are most variable of all in form; common among them are lanceolate forms (fig. 3, *c*), covered with fine hairs. The average size of the scales is about 0.10 mm. long by 0.05 mm. wide, and they are attached to the insect by a more or less prolonged basal portion (fig. 3, *a-c*); they lie very flatly pressed upon the surface of the insect.

Most of the scales of the dorsal surface of the thorax and of the elytra, when viewed by transmitted light, are bright canary yellow, but many of them are tinged with carmine red. Viewed by reflected light, or upon a dark background, the parts before yellow are bluish, or dark and nearly invisible, while all the parts before reddish are now dark and more or less indistinct (or rarely greenish if they were purplish-red before). If the stage of the microscope is now revolved, and the light to be reflected from the scales is thus brought from a different direction in regard to the scales, some of the parts before dark become bright bluish while others just before blue become darkened, but in no case do parts of a scale which were reddish by transmitted light become bluish by reflected light. If the light is not excluded from above the stage of the microscope, when examining these scales by transmitted light, places will be discovered, where the scales are injured or where they are turned up at their margins, in which bright blue, or rarely green, will be seen. In all cases where I speak of transmitted light I have excluded the light from above the stage of the microscope, and where I speak of reflected light I have excluded light from below the stage of the microscope.

If the scales are in any way injured or cracked, as they usually are in removing them from the insect, water will readily enter them and discharge the air from them. Scales thus treated with water are, by transmitted light, sky blue, sometimes tinged with carmine red, the latter color being in portions of the scales which had not been thoroughly penetrated by the water, for while the water is entering the scales they become reddish for a time before changing to blue. Boiling the water a minute causes all red to disappear but seems to have no further action on the scales; their structure is not altered, as the water inside such minute cavities is not readily boiled. By reflected light many scales that have been treated with water are dark greenish.

Glycerin produces nearly the same effects in these scales as water does; its action is, however, slower and gives more opportunity to examine the scales during the process of saturation. Light transmitted through scales that are treated with glycerin is nearly colorless, and reflected light from scales thoroughly penetrated with glycerin is, for the most part, colorless; sometimes, however, it is greenish in spots, and these spots are usually where a tinge of red remains, when viewed by transmitted light.

In absolute alcohol the scales show, by transmitted light, a more reddish tinge than they show in water; in chloroform the tinge is more purplish than in water, altho the purple is very pale; in turpentin and in oil of cloves the scales are transparent and colorless. Scales moistened with any of these reagents and put over a dark or black surface are light metallic green; if dry scales are put over dark surfaces they are light metallic blue. Redried from water, alcohol or chloroform these scales regain their original colors, showing that it is a coloration due to the structure of the scales and not due to any pigment in them. In further proof of this I exposed the scales to dry chlorin gas and the color remained unaltered. Solutions of chlorin or of hypochlorites fail to destroy the coloration, for after they are washed out and the scales again dried the colors reappear as bright as at first.

Dry scales heated slightly over flame suddenly lose all their metallic coloration, and, while retaining their form, become brownish grey by transmitted or reflected light; they are apparently charred sufficiently to lose their color without having their structure greatly altered.

In structure these scales are readily seen to be little flattened sacs; wherever they are injured, especially if they are broken off near the base, the edges of the upper and lower sides appear distinctly. The inner structure of these scales is not easily discoverable. They appear to be filled with a very delicate network (fig. 3, *d*), which is always reddish after the yellow has left the scales. If glycerin is used as a reagent in treating the scales their reddish network, even in scales originally yellow, remains long after the yellow has disappeared. The yellow occupies the interspaces of the network. The network itself, under high powers, appears as if it were caused by retiform designs in reddish oil between the layers of the scales, but the fact of the reappearance of the color after treating the scales with solvents for oil, *e. g.*, chloroform, shows that it is not oil. From the appearance of scales charred to different extents I am inclined to think this network to be formed by thickenings of the chitin walls of the scales themselves. If this be the case, the thickenings project only inward from these walls, and are found in corresponding figures upon both upper and under walls of the scales. The colors red and yellow by transmitted light may exist where only the upper or under half of the scale is present.

(*To be continued.*)